

REGISTRATION CHARACTERISTICS OF NEUTRAL PARTICLES WITH
POWER 0.6 - 2.0 KEV CHANNEL ELECTRON MULTIPLIER
WITH FUNNEL

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16. Abstract A study was made of operating a channel electron multiplier with a VEU-6 funnel shaped opening. Different procedures were used when recording neutral particles. The results obtained make it possible to optimally use the multiplier in actual physical studies.			
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REGISTRATION CHARACTERISTICS OF NEUTRAL PARTICLES WITH
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Modern science and technology presents more and more serious /2* requirements for recording equipment. Among the instruments which are widely used in many fields of experimental physics, when solving problems of recording different types of radiation, flows of neutral particles, ions, electrons, one can remark on secondary electron multipliers (VEU [vtorichnyy elektronnyy umnozhitel', secondary electron multiplier]). The primary particle entering the VEU, gives a signal at the output suitable for recording and then the VEU has an extremely low noise level. The secondary electron multiplier operates in a vacuum and vacuum dense shells are absent in them. The greatest advantage of the VEU is their very high sensitivity. Whereas the use of the Faraday cylinder can measure current up to 10^{-16} amperes, the use of VEU as detectors, especially operating in a discrete count of particles procedure makes it possible to decrease this limit by several magnitudes. Moreover, the VEU makes it possible to directly record flow of neutral particles with the power of several hundred electron volts and more. Recently, secondary electron multipliers have been widely used with a continuous dynode, in particular, channel electron multipliers (KEU [kanalovyy elektronnyy umnozhitel', channel electron multiplier]). Diagrammatically, the KEU is a tube made of resistive material which can be of various shapes and at whose /4 end the difference of potentials is applied on the order of several kilovolts. The recorded particle colliding with the internal wall at the beginning of the tube has electrons dislodged from it which move inside the tube accelerating under the effect of the applied difference of potentials and, themselves,

*Numbers in the margin indicate pagination in the foreign text.

in turn collide with the wall of the channel, dislodging electrons forming an avalanche which is recorded at the output. Funnels can be used for increasing the input aperture of the KEU.

Simplicity of design, small dimensions, insignificant requirements for power, high coefficient of amplification (up to 10^8), the capability to transfer significant impact in vibration loads, and the repeated effect of the atmosphere made the KEU an irreplaceable instrument for studying outer space from the satellites. Ultraviolet and soft X-ray radiation, the atmosphere and ionosphere of Earth and other planets, interplanetary space and solar wind are all studied using channel electron multipliers.

In most of the published works, the characteristics of channel electron multipliers are considered when recording electrons [1-3], ions [4] and ultraviolet radiation [5, 6], at the same time comparatively little attention was devoted to recording neutral heavy particles [7]. In this work, detailed measurements were made of band characteristics, amplitude spectra, fatigue characteristics, effects of load, relationships to the nature of the recorded particles of the domestic channel electron multiplier with a VEU-6 funnel [8] when detecting neutral particles with a power of $E = 0.6\text{--}2.0$ keV. Certain results obtained were presented in reference [9].

For the measurements, a unit [10] was used in which a beam of neutral atoms was created by recharging of ions; the beam was recorded in the VEU-6 (Figure 1). The collimated beam has a trapezoidal shape with characteristic dimensions 0.2 mm (Figure 2) and in comparison with the characteristic dimensions of the VEU-6 (diameter of the input funnel $\varnothing_f = 8$ mm, diameter of the channel $\varnothing_c = 1.5$ mm) can be considered as precise which made it possible to obtain band characteristics of the multiplier, that is, the

relationship of the parameters of the multiplier to the point of entrance of the beam to the input funnel. During the experiments, pressure was maintained at a level of 10^{-6} mm mercury column. The multiplier was mounted on the mobile platform which has two degrees of freedom and moves in a plane perpendicular to the axis of the beam. Negative voltage U_k was supplied at the input of the channel electron multiplier and was grounded at the output. This method is standard for recording slow charged particles when preacceleration of the input potential is used. The signal from the VEU-6 went out on the pulse amplifier and further to the scaler PP9-2M instrument and the amplitude pulse analyzer, the AI-1024. Amplitude distribution of pulses obtained by the AI-1024 instrument were recorded by a two coordinate PDS-021 M recorder (Figure 1). Standardization of the distributions obtained was carried out according to "area", that is, to the full number of recorded pulses.

In order to study the relationship of the characteristics of the VEU-6 of the nature of detected particles, flows were recorded of helium, hydrogen, molecular nitrogen with energy of the particles $E_p = 1200$ eV. It appeared that amplitude distribution of pulses hardly depends on the nature of the particles of the flow detected. Therefore, all of the results presented below are obtained for beams of He atoms.

Figure 3 shows the lines of a uniform rate of counting according to area of the input VEU-6 funnel. As is apparent, the multiplier has a fairly good axisymmetry and therefore in the future when studying band characteristics, the detector was shifted in such a way that the beam fell sequentially on points of the input funnel, lying along one of its diameters. The band characteristics are of particular interest for the channel electron multiplier with a funnel. Knowledge of them is necessary both for operating with adequately narrow bands and for understanding the peculiarities of the functioning of the multiplier. /6

Figure 4 shows the results of measuring the counting rate depending on the point of introduction of the beam with constant intensity at different voltages U_k on the VEU-6. Measured relationships of the rate of counting were modulated with a network step and then changes in intensity of the beam on the plateau reaches 25%. In distinction from a case of recording electrons, ultraviolet and ultra soft X-ray radiation [2, 5], the rate of counting for neutral particles does not increase when the beam strikes the center of the funnel. Consequently, the effectiveness of recording in the center of the funnel for neutral particles in the field of energy studied does not increase. With a decrease in voltage on the multiplier, beginning at $U_k = 2400$ V, a depression at the center of the band characteristics is apparent and the level of discrimination of the PP9-2M scaler instrument remained unchanged. As will be indicated below, this is due to a decrease in the coefficient of amplification of the channel electron multiplier $K\alpha$ both with a shift in the beam from the edge of the funnel to the center and with a decrease in voltage U_k which results in the fact that the pulses recorded stop below the level of discrimination of the scaler instrument which usually is set up in such a way that the intensity of the background did not exceed 0.1 pulses per second.

Figures 5a, 5b, 5c show amplitude distribution of pulses at the KEU output for a beam of helium atoms with energy $E_p = 600$ eV with different values of U_k and with the beam striking different points of the funnel. Using these distributions, it is possible to obtain a relationship of the relative coefficient of amplification $K\alpha$ by which [2] the value of the most probable pulse is understood in amplitude distribution from the position of the detected beam and from voltage on the VEU-6. One should note that in Figure 5, as in all the subsequent drawings on which amplitude distributions are presented, not all of the measured relationships are indicated but only the most typical. Figure 6 shows the relationship of $K\alpha$ to voltage on the multiplier for $r = 0$ and $r = 3$ mm. They are straight lines whose angle of

inclination to the axis of the abscissa increases with distance from the incident point of the beam from the center of the funnel to the edge. This attests to the fact that K_α increases with an increase in U_k and also with distance from the incident point of the beam from the center of the funnel. Figure 7 shows the relationship of the relative coefficient of amplification K_α to distance from the center of the funnel with two values of U_k ($U_k = 2500$ V and $U_k = 3500$ V) and for the energy of the beam $E_p = 600$ eV and $E_p = 2000$ eV. It is apparent that when $E_p = 600$ eV, just as for the electrons [2], K_α decreases when approaching the center of the funnel. This occurs, probably due to a decrease in the effective method of multiplying the electrons, that is, the beam is directed toward the center of the funnel, the electrons are dislodged from the channel, the voltage of the multiplier which, accordingly, is smaller than for electrons dislodged from the funnel. With an increase in energy of the beam to $E_p = 2000$ eV, K_α becomes uniform for the entire area of the input funnel.

The relationship of the rate of counting l to voltage on the multiplier U_k with a fixed level of discrimination of the scaler instrument is shown in Figure 8. Curves are presented for cases of the beam falling at the center of the funnel and at a distance of 2 mm from the center. The curves obtained have a complex character and in the field of voltages and energy studied did not form a plateau but had a tendency to increase the rate of counting l with an increase in voltage on the multiplier U_k . We note that for the center of the funnel, increase l (U_k) when $U_k > 2400$ V amounts to 10% per 300 V. Similar results are obtained when recording ultraviolet radiation on the Mullard B 419VL KEU [6]. It was noted that the relative path-width of distribution, that is, the ratio of the width of distribution to the level one-half of its height to the value of the most probable pulse increases with a shift of the beam from the edge of the funnel to its center (Figure 9). The relationship of the relative half-width to voltage with different values of r has a fairly complex

character showing a weakly expressed minimum $U_k = 3000\text{--}3300$ V, and then we note that the half-width changes more strongly at $r = 0$.

Figure 10a shows the distribution of pulses with $U_k = 3500$ V, $r = 0$, for beams with energy $E_p = 600$ eV and $E_p = 2000$ eV. It is apparent that when increasing the energy of recorded particles from 600 eV to 2000 eV, the size of the most probable pulse and, correspondingly, the coefficient of amplification K_a increased approximately by 1.5 times. With a shift in the beam from the center of the funnel to the periphery, a shift in distribution of pulses also occurs in the field corresponding to the largest value of pulse which is explained by the increase in the coefficient of amplification (Figure 10b).

The form of distribution of pulses has a very interesting appearance when the beam strikes the center of the VEU-6 funnel and for U_k which exceeds 3300 V. One clearly observes a second bulge in the curve which corresponds more to the pulse value. Thus, for example, at a voltage of $U_k = 3500$ V and beam energy $E_p = 600$ eV, the height of the second peak exceeds by 30% the height of the base peak. One should note that the two peak distribution was observed only when the beam approaches the center of the funnel. The ratio of the contribution of the small peak to the contribution of the basic peak to the integral signal at the output of the KEU changes in a complex way. With an increase in U_k , this ratio at first noticeably increases and then changes fairly weakly (Figure 11). /9

Knowledge of the relationship of the characteristics of the multiplier to the load is extremely important for different types of measurements. Figure 10c shows amplitude distributions for a beam of helium atoms with energy $E_p = 600$ eV, $r = 0$, $U_k = 2500$ V with intensity of the beam $I = 4000$ pulse/s, $I = 40000$ pulse/s, $I = 120000$ pulse/s. It was apparent that when changing the

intensity of the beam to 4000 pulse/s neither the shape of distribution of the pulses nor the coefficient of amplification depends on the multiplier load. However, when increasing the intensity of the beam from 4000 pulse/s to 120000 pulse/s, the coefficient of amplification K_a drops approximately by two. For studying fatigue characteristics, the VEU-6 undergoes the effect of a beam of ions of hydrogen H^+ with intensity $I = 10^6$ pulse/s for a period of three hours. It was established that the coefficient of amplification K_a decreases approximately by 10 times with a set of the full number of computed pulses 10^{10} .

The results obtained show a number of features in the characteristics of the VEU-6 when recording neutral particles. Knowledge of these characteristics makes it possible to use the VEU-6 in an optimum way in actual physical studies.

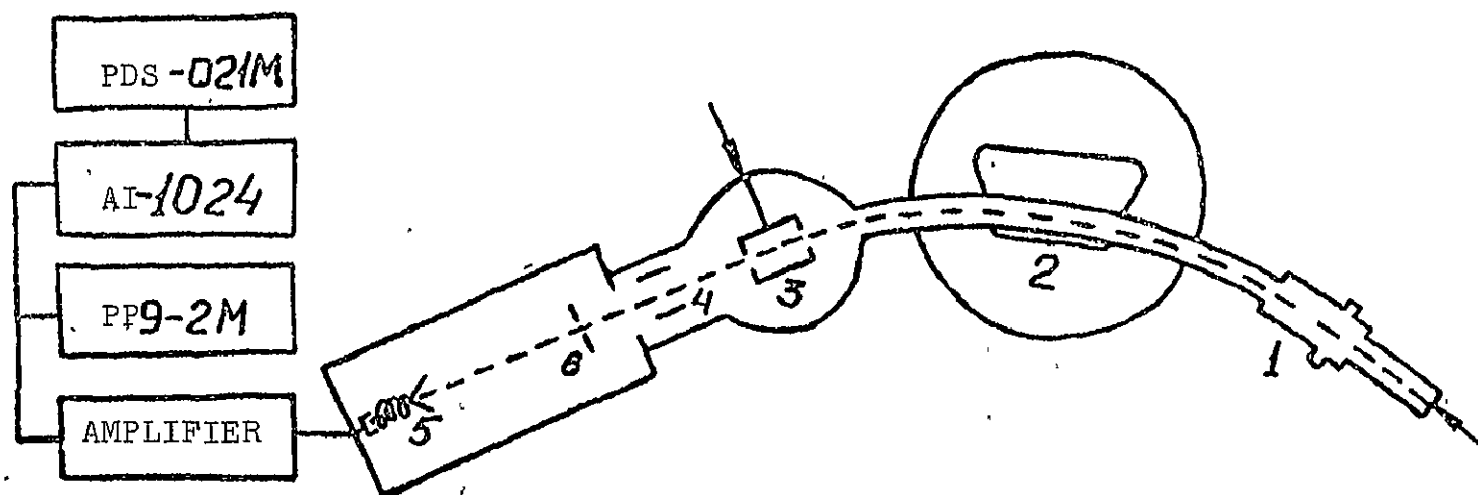


Figure 1. Diagram of the unit: 1--ion source; 2--magnetic analyzer; 3--charge chamber; 4--deflecting capacitor; 5--channel electron multiplier VEU-6; 6--diaphragm.

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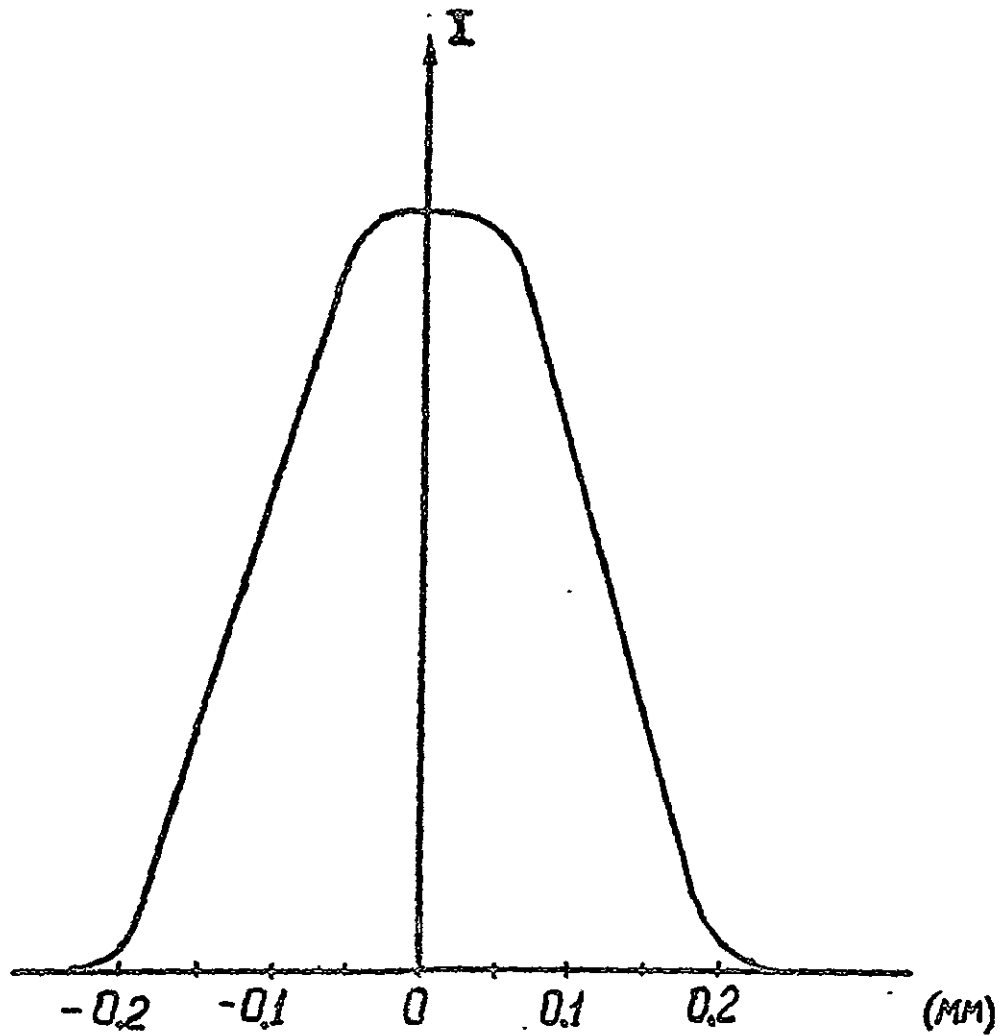


Figure 2. Radial distribution of intensities of the beam (along the ordinate axis, intensity is presented in relative units).

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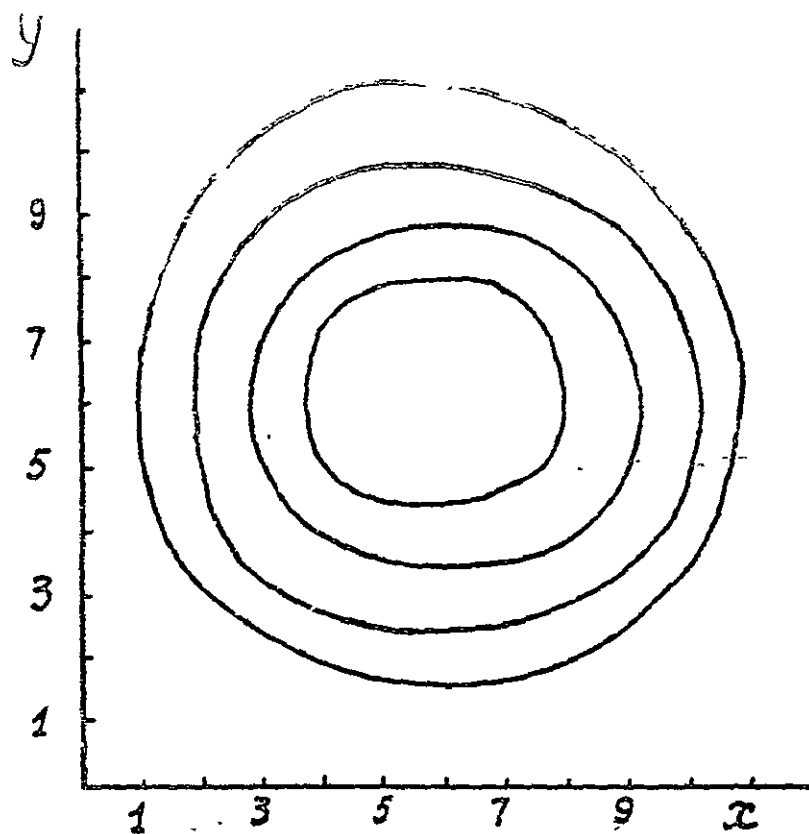


Figure 3. Lines of uniform rate of counting according to area of input funnel VEU-6 (x and y in relative units).

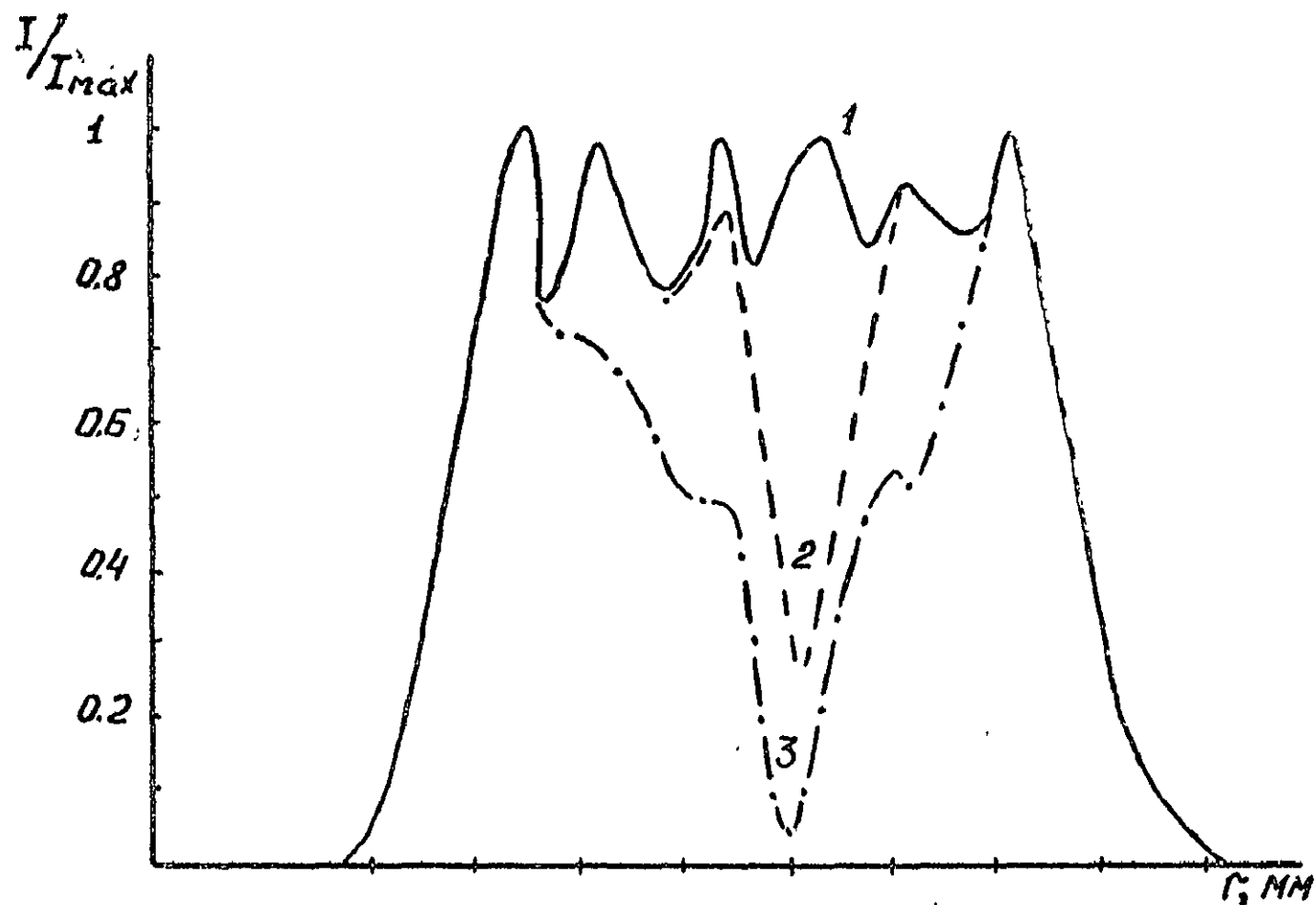
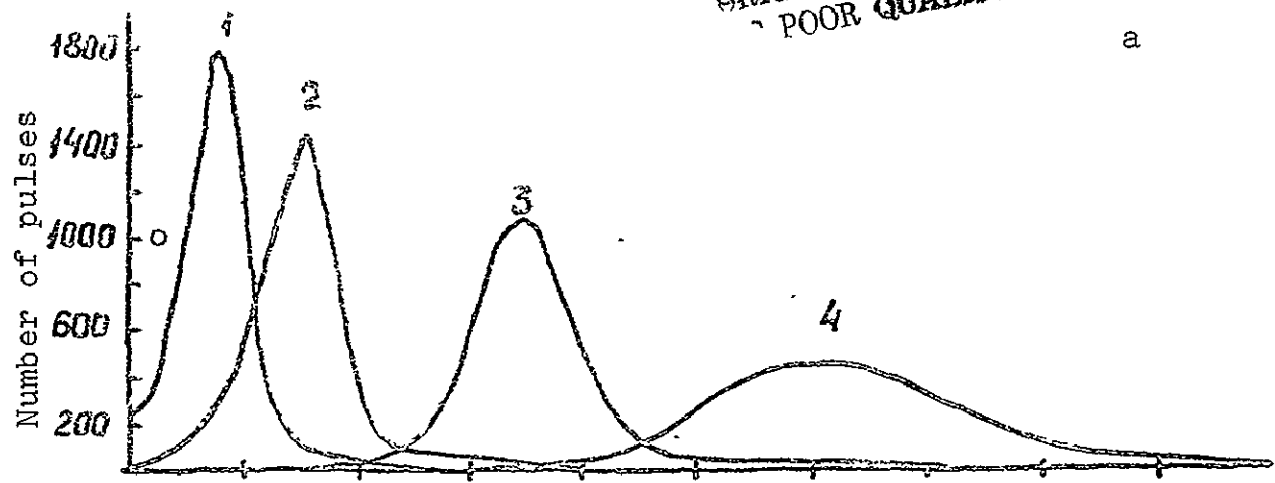
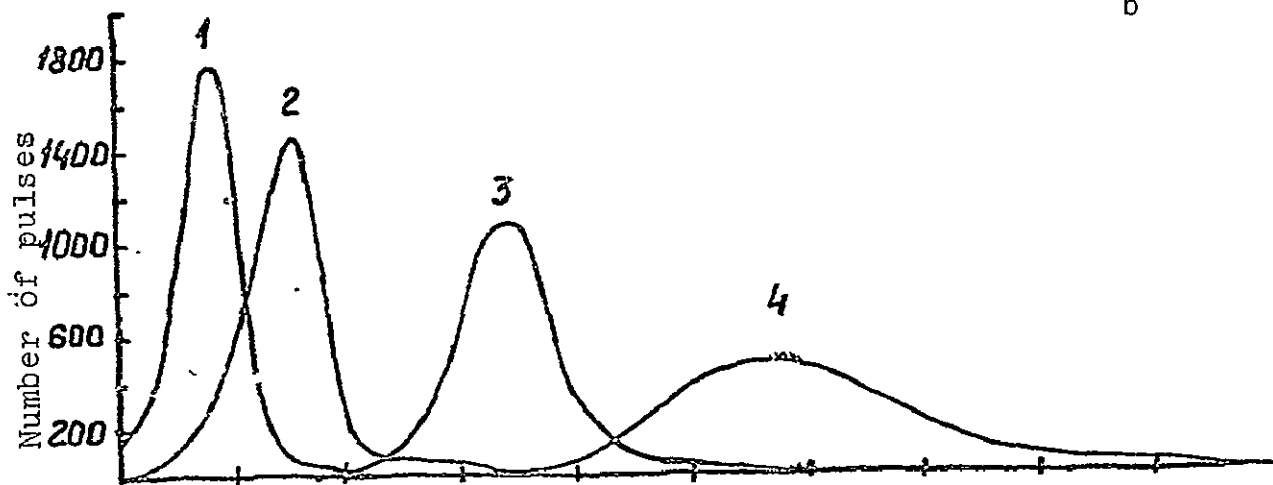


Figure 4. Relationship of the counting rate to distance to the center of the funnel. 1-- $U_k = 2600$ V, 2-- $U_k = 2200$ V, 3-- $U_k = 2000$ V; $E_p = 600$ eV.

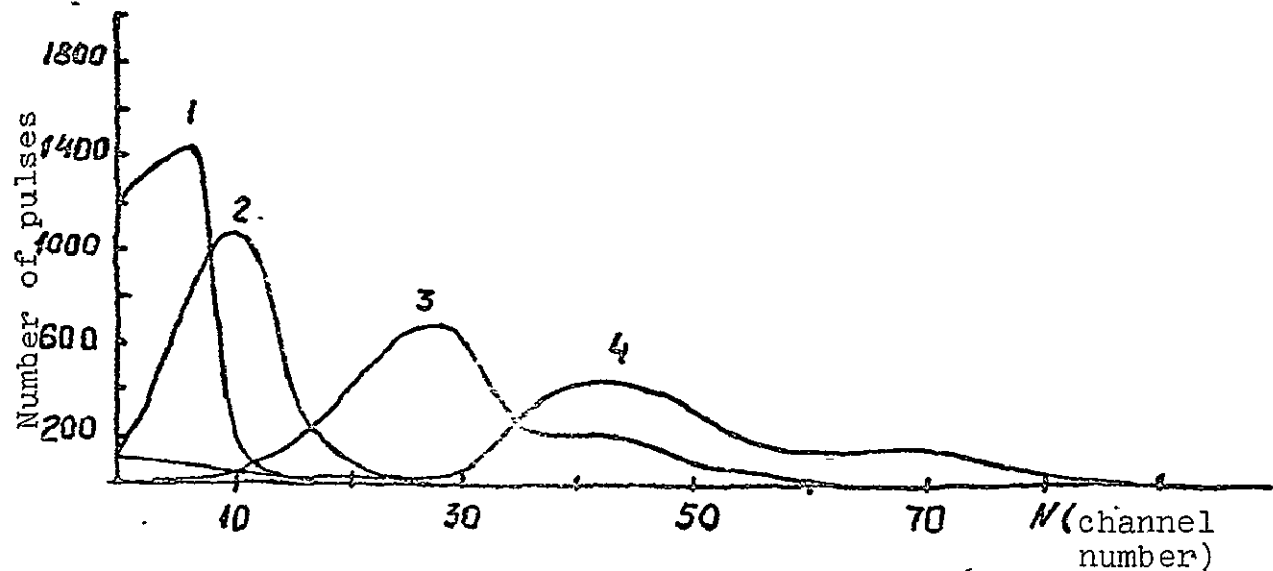


a

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b



c

Figure 5. Amplitude distribution of pulses with different voltages U_k : 1-- $U_k = 2300$ V, 2-- $U_k = 2500$ V, 3-- $U_k = 3000$ V, 4-- $U_k = 3500$ V. Distance from the center of the funnel a) $r = 2.5$ mm, b) $r = 2.5$ mm, c) $r = 0$.

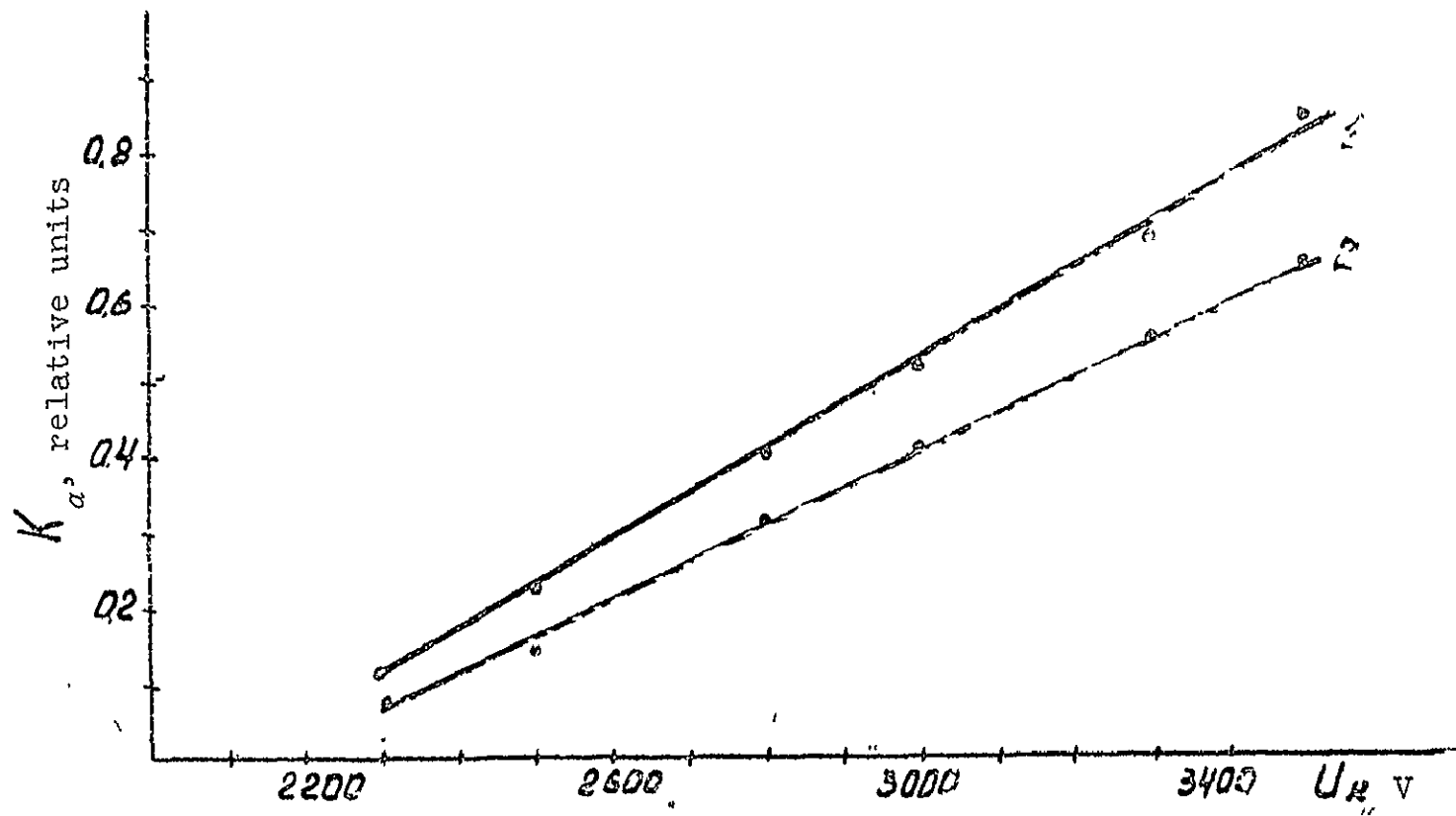


Figure 6. Relationship of the coefficient of amplification to voltage U_R . Distance to the center of the funnel 1--articles 3 mm, 2--articles 0; $E_p = 600$ eV.

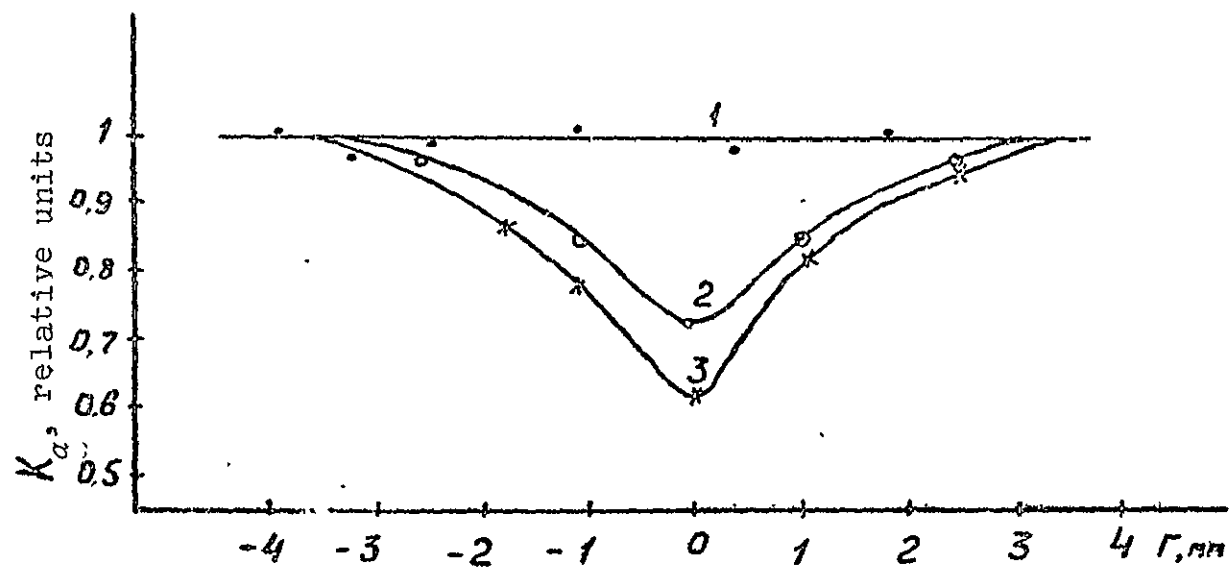


Figure 7. Relationship of the relative coefficient of amplification to the distance to the center of the funnel 1-- $U_k = 2500$ V, $E_p = 2000$ V; 2-- $U_k = 3500$ V, $E_p = 600$ eV; 3-- $U_k = 2500$ V, $E_p = 600$ eV.

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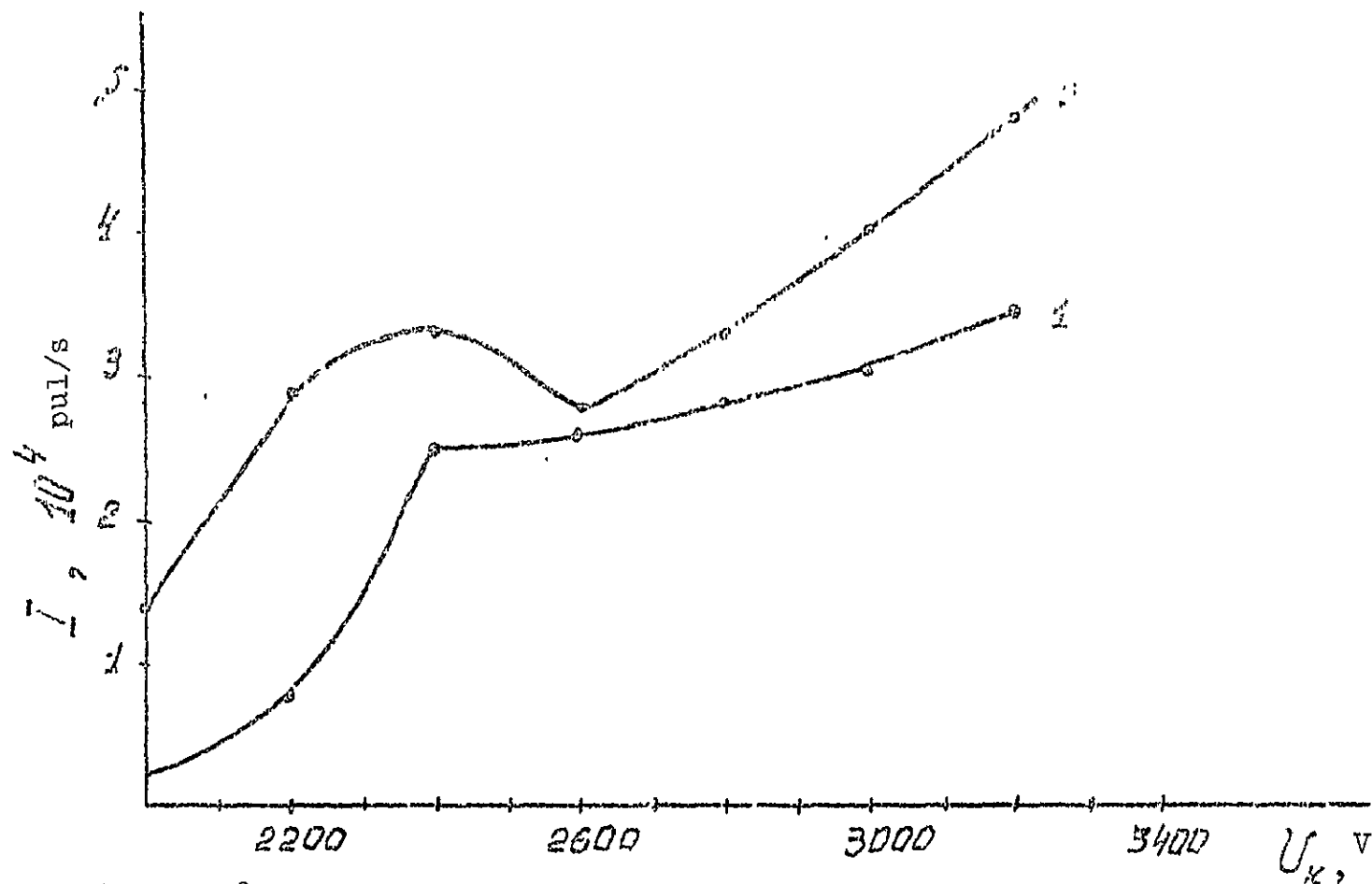


Figure 8. The relationship of the rate of counting to voltage U_k . Distance to the center of the funnel 1-- $r = 0$, 2-- $r = 2 \text{ mm}$; $E_p = 600 \text{ eV}$.

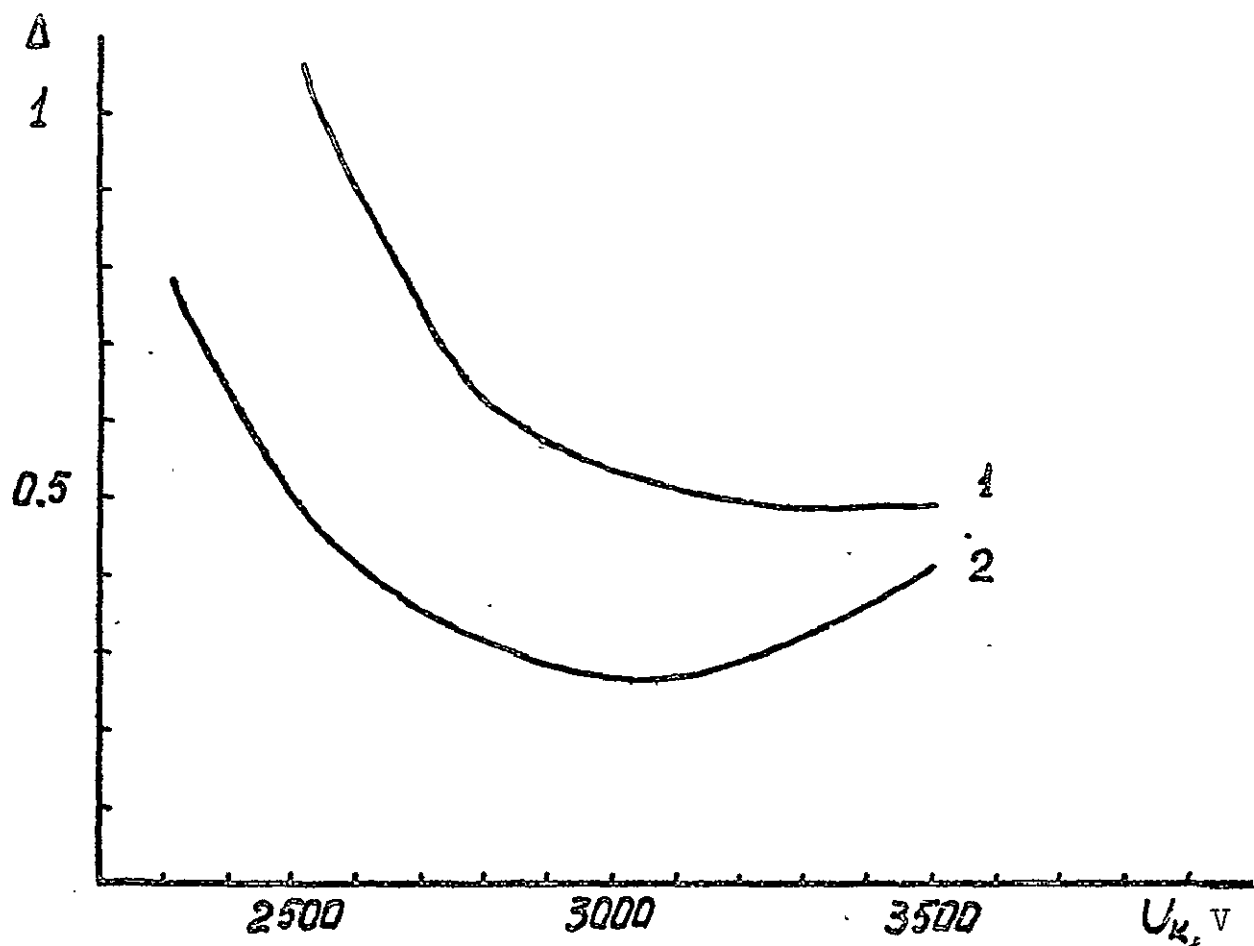
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Figure 9. Relationship of the relative half-width of distribution to voltage U_k for different points of incidence of the beam: 1-- $r = 0$; 2-- $r = 3$ mm.

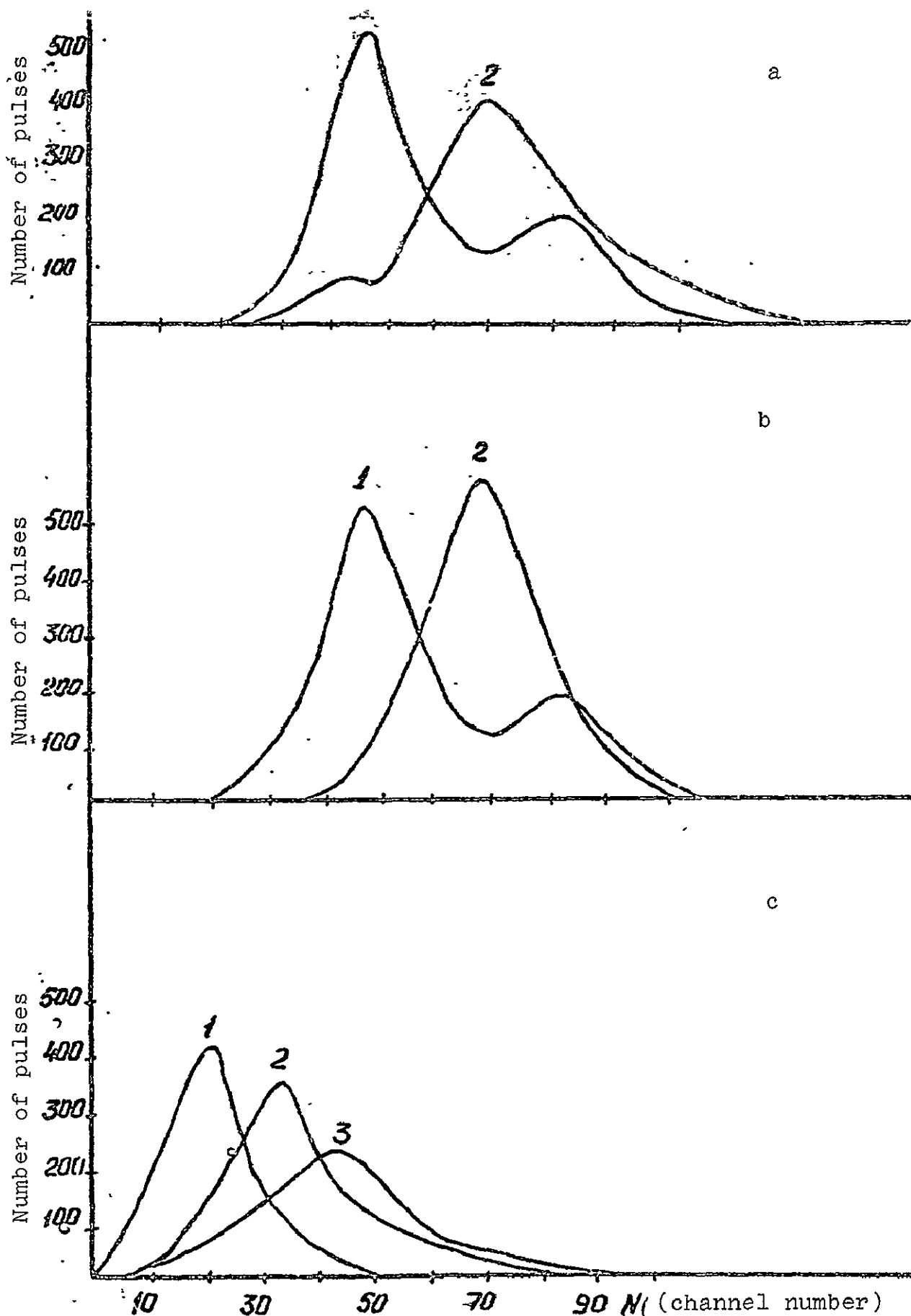


Figure 10. Relationship of the ratio of contribution of the small "peak" to the contribution of base "peak" R in amplitude distribution to voltage U_k ; $r = 0$; $E_p = 600$ eV.

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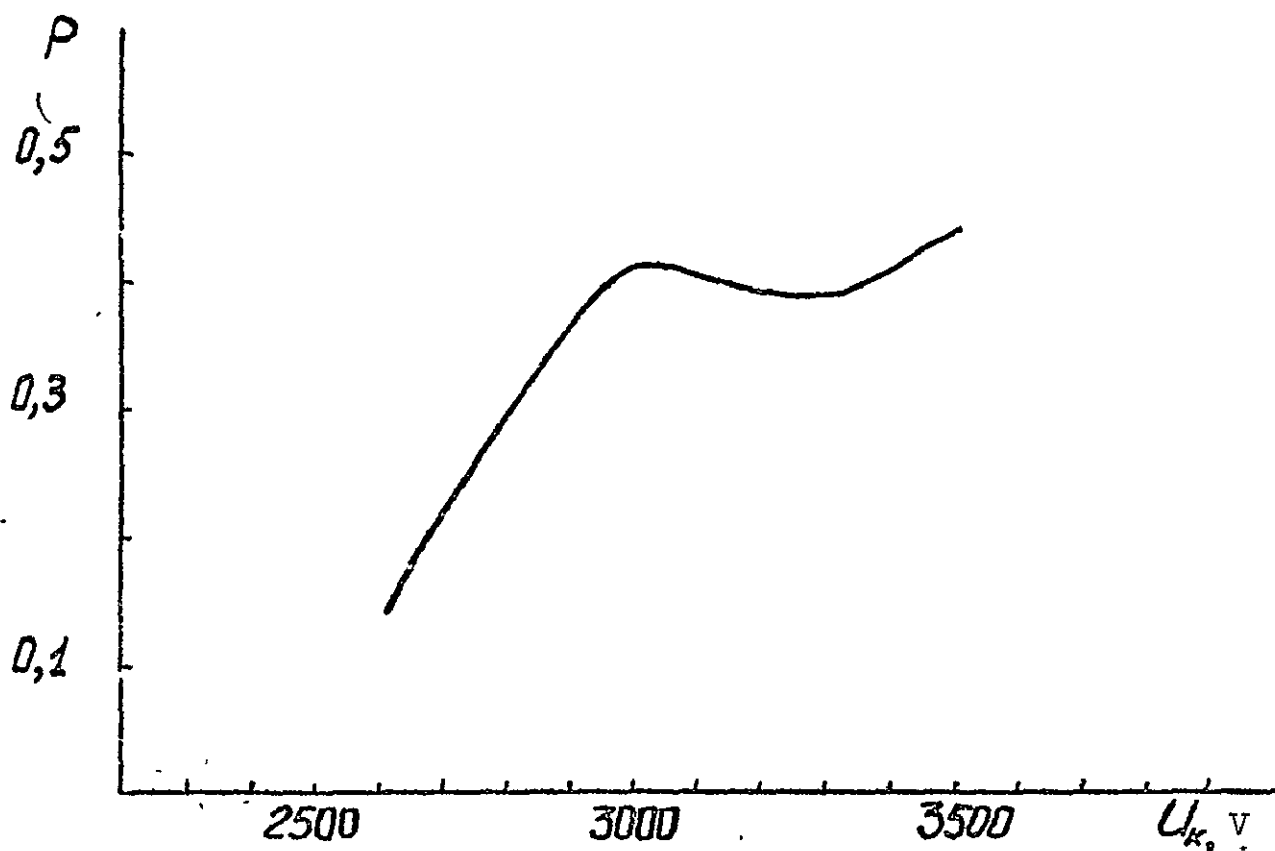


Figure 11. Amplitude distribution of pulses: a) in relation to the energy of the beam, 1-- $E_p = 600$ eV, 2-- $E_p = 2000$ eV, $U_k = 3500$ V, $r = 0$. b) in relation to the distance from the center of the funnel 1-- $r = 0$, 2-- $r = 2.5$ mm, $U_k = 3500$ V, $E_p = 600$ eV. c) in relation to load 1-- $I = 1200$ pul/s, 2-- $I = 40000$ pul/s, 3-- $I = 4000$ pul/s, $U_k = 2500$ V, $E_p = 600$ eV, $r = 0$.

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